Overview of LHCb electronics installation aspects

V. Bobillier, L. Roy, J. Christiansen

CERN, 1211 Geneva 23, Switzerland

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Abstract

The infrastructure for the electronics, such as cabling, mains power distribution, low and high voltage power supplies, detector safety system, grounding and its installation in the LHCb experimental cavern is presented. In addition, racks, cable ducts installation and optical fiber link tests are described.

I. INTRODUCTION

LHCb presents some particularities compared to other LHC experiments due to its geometry (forward coverage only). This geometry offers the advantage that most sub-detectors are constructed in two halves that can be opened for maintenance. Accessibility to the on-detector electronics is therefore reasonably easy and equipment such as power supplies can be installed relatively close to front-end electronics. On the other hand, the fact that sub-detectors can be opened implies specific constraints for cabling and grounding of sub-detectors.

A 4 meter thick shielding wall made of concrete blocks protects DAQ interface electronics and a large PC farm of ~2000 computing nodes against radiation. The PC farm and DAQ interface electronics are installed in racks in barracks on 3 levels (counting house). Cabling from sub-detector specific in/on detector front-end electronics to the protected counting house has lengths of 50 to 110 meters. The shielding wall acts as an important obstacle for all power, readout and control services that have to pass through a narrow chicane.

II. RACKS

Two types of standard 19” racks are used in LHCb; one with standard vertical closed air flow for the front-end electronics and another with open horizontal air flow for the computing farm PCs. The front-end electronics racks (~50 units) use the common LHC turbine units, heat exchangers and deflectors while a custom ventilated and water cooled rear door has been developed for the PC racks (~80 units). This water cooled and ventilated rear door unit is also used by the Alice experiment and similar system is used in CMS and Atlas. Rack mountable PC units need to be cooled by horizontal air flow. PC units are hermetically closed on top and bottom and are designed to suck fresh air via their front panel.

The two bottom levels of the counting house are used for the computing farm and its main components while the third floor receives the front-end and DAQ interface electronics of the sub-detectors.

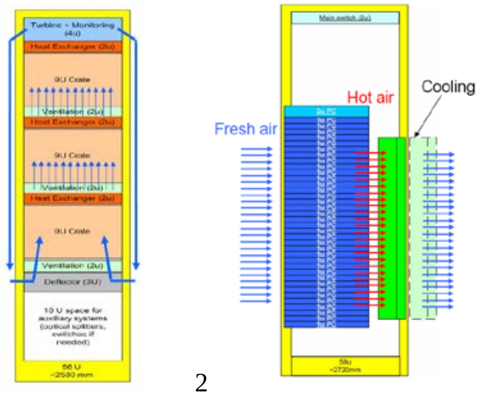

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Figure 1: Front view of front-end racks (1) and side view of PC racks with rear cooling door unit (2)

III. RACK CONTROL AND MONITORING

The rack control and monitoring system consists of different infrastructure systems: the mains electrical distribution network and its remote control, the Detector Control System (DCS), also called Experiment Control System (ECS), the Detector Safety System (DSS), the rack monitor board (in the turbine units) and their ELMB based sensors and the smoke detector network and its PLC [1]. The system monitors principally the temperature, the rotation of the turbine motors and the presence of smoke in the racks. The control part can cut the mains power in racks via the DCS (soft manner via the local mains electrical power supervision system) under normal conditions or via the Detector Safety System (DSS) (brute force manner via interlocks) in emergency cases. In the frame of the rack control and monitoring system, DSS also offers the possibility to manually and remotely trigger the fire extinguisher in a given group of racks. Two different fire extinguisher systems are used in LHCb. Individual CO2 injection for the front-end electronics racks and a water mist system for the entire barracks where CPU farm racks are installed.

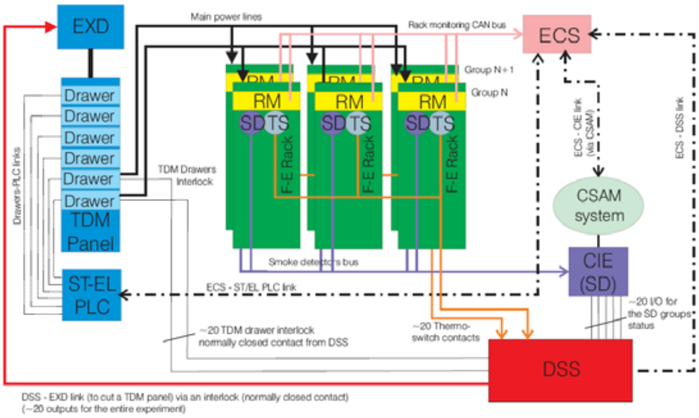

Figure 2: Rack control and monitoring working principle

IV. DETECTOR SAFETY SYSTEM (DSS)

The basic detector safety system is a common project used in all 4 LHC experiments. However, it is used in different manners across experiments. The purpose of this system is to intervene in case of emergencies when ECS has not intervened in time to protect expensive or rare equipments in the cavern and counting house (example: cut power when over temperature is detected, stop water cooling in case of leakage, etc.). Its actions are based on a number of sensors placed in critical locations. In LHCb it has been decided to use this safety system for the detector in a simple and unified manner across sub-system to get a reliable system [2].

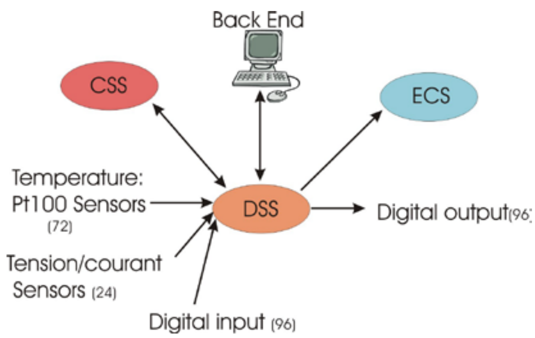

Figure 3: DSS and its main links

The number of inputs and outputs available per sub-detector is limited in order to keep the system simple. This has the advantage, in addition of keeping the system at a reasonable size, of simplifying the cabling and reducing the possibility of errors. Only certain types of sensors are proposed to sub-detectors. Unified approach is given to sub-detectors for the choice, number and placement of their sensors. Thermo-switches are installed and trigger an alarm when a certain temperature is reached. Thermo-switches are daisy chained in groups and are placed where overheating can possibly damage equipment. PT100 measuring temperatures are limited to a few per sub-system. Water leak detection sensors are fixed where water cooled equipment are located. Based on these sensors, the DSS has the possibility to automatically cut mains electrical power to equipments, close the valves of the cooling network or shut down HV for a given or a group of sub-detector(s).

V. MAINS ELECTRICAL POWER DISTRIBUTION

The mains power distribution network supplies all the permanent consumers that are directly related to the experiment itself. This includes the front-end electronics, the data acquisition system as well as other services and sub-systems such as cooling, gas and vacuum systems [3].

It has been decided to separate electrically the computing farm and the front-end electronics racks by using two 1.25 MVA transformers due to the fact that the online computing farm made of approximately 2000 PCs is expected to be a "bad" consumer (with poor quality power factor correction, PFC), inducing a non negligible dose of harmonics [4]. This has been made to avoid mains electrical power with high harmonics disturbing the sensitive front-end electronics.

Power from the mains transformers is distributed to the sub-system via 2 levels of distribution panels. The granularity for the power system is for groups of maximum 3 racks. Groups have been made for sub-detector halves (left/right separation) or for entire sub-detector (for smaller sub-systems). A local supervision system (PLC based) offers monitoring and basic control capabilities. DSS can turn off groups on emergency cases (via interlocks) when DCS or supervision system are not able to intervene. In the racks power is locally distributed via a 3U distribution box with 7 single phased outlets.

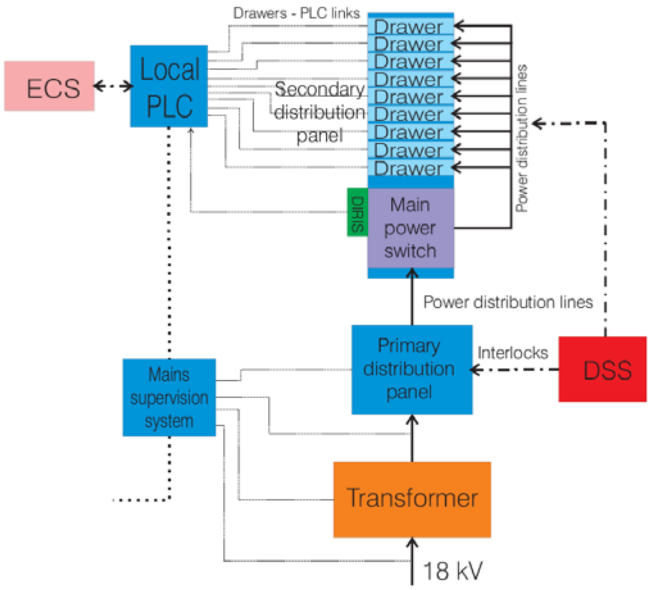

Figure 4: Overview of mains electrical power distribution principle

Front-end power supplies are all of the switching mode type and equipped with soft start system to limit inrush current and with active power factor correctors (APFC) [5]. PCs are most often not equipped with soft start systems and have been seen to have important inrush currents when turned on.

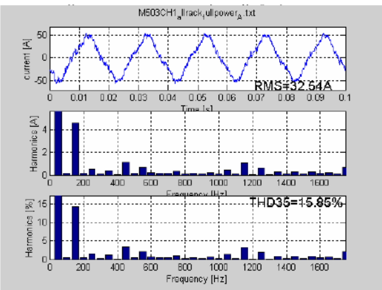

Figure 5: Measurement of total harmonic dose (THD) on a PC farm rack

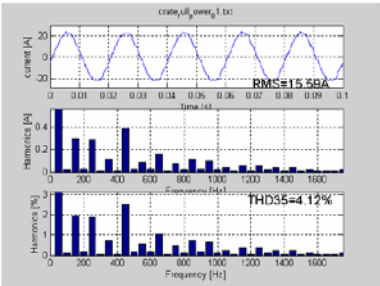

Figure 6: Measurement of THD on a standard crate low voltage power supply

It has been decided to implement adjustable temporization relays in the in-rack distribution boxes as the possibilities offered by the different standard types of circuit breaker trigger curves were not sufficient to deal with important inrush currents of the computing farm racks. In addition, rack groups (maximum 3 racks) are cascade started one after the other using the remote control feature of the distribution panels.

In the counting house, mains electrical power cables are installed on the ceiling in order to separate them from the sub-detector cables in the false floor. This reduces the risk of 50Hz parasitic coupling with sub-detectors sensitive cables.

VI. Low voltage power supplies

Recommendations have been made to LHCb sub-detectors to standardize as much as possible the type of low voltage power supplies used in the experiment. This, in addition to offering the possibility of organizing common spare parts across the sub-detectors gives us the following advantages: standardizing cable infrastructure and patch panels; possibility for all users to exchange knowledge and experience with equipment; standardizing the control (with DCS, PVSS) of those LV units.

Except the Vertex locator because of its requirements (large number of low power channels), all LHCb sub-detectors use the Wiener power supply system with radiation tolerant DC-DC converter (380Vdc to very low voltage, 2 to 8 Vdc for example). These DC converters can house a maximum of 12 channels of 300W maximum each and are installed relatively close to the on-detector front-end electronics as the geometry of LHCb favourably offers some locations with limited radiation level (few kRad).

All DC/DC converters used in LHCb are cooled by mixed water due to the important magnetic field present in the experimental cavern (fan cannot be used). The DC converter offer basic remote control and monitoring capabilities. The remote monitoring and control rely on a number of differential links per channel. AC-DC converters with APFC as well as the control modules are installed in the counting house racks, approximately 70 meters from the DC converter. 2 control cables and 1 power cable of reasonable thickness (current limited because of the relatively high voltage 380Vdc) are required per power supply.

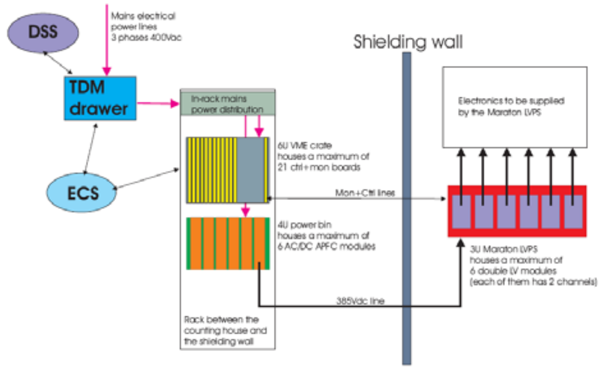

Figure 7: Low voltage power supply schema

All sub-detectors use radiation tolerant linear voltage regulators. These regulators are used to supply all local front-end electronics. Low voltage regulators form an additional filter for possible ripple at the input of the front-end electronics.

VII. Cabling

Chicane passages are present on both sides of the 4 meter thick shielding wall made of concrete blocks. These two chicanes of approximately 4 meter high by 350 mm large form two sections allowing the passage of all services going from the sub-detectors to the protected area where experiment and infrastructure electronics and control modules are installed. This includes, apart from the copper and optical fiber cables for data-readout, power and control (occupying half of both chicanes), all cooling, ventilation and gaz pipes and all mains electrical power distribution cabling. Due to the large amount of sub-detectors cables with important cross-sections, an existing groove in the cavern concrete floor is used as well for routing the cables.

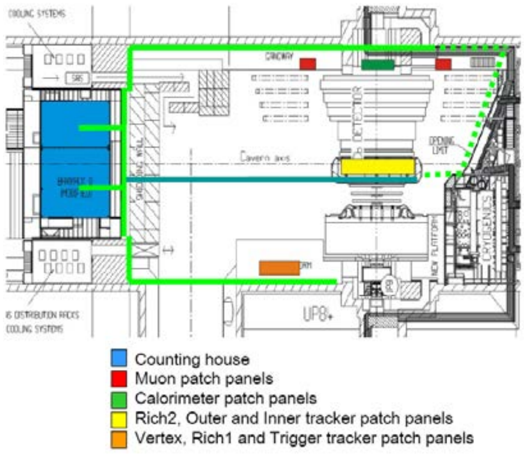

Figure 8: Overview of main cable routes in cavern

Patch panels decoupling the long distance links going to the counting house from the moveable parts of all links are used [6]. This offers the possibility of exchanging possible broken links easily in the moving cable chain where probability of broken cables is high. At the same time it offers the possibility to install spare links in the movable cable chain where installation is difficult due to the poor accessibility.

All commonly used cables, across sub-detectors, (for LVPS, CAN bus and other control links) are chosen with shielding for EMC reasons. Recommendation is made to all sub-detectors to use shielded cables.

All experiment cables (for sub-detectors, ex.: readout, control and power) are supported by metallic closed (covered) cable ducts for EMC reasons. Each sub-detector has its cables installed in a cable duct separated from other sub-detector's cables. When and where possible, one cable duct is used for each cable type (power, control and readout) otherwise a metallic separator is installed in the cable duct in order to avoid different cable types being installed close to each other.

All long distance copper cables from sub-detector patch panels to counting house are first pulled without connectors. Connectors are then installed on cables in a second phase. This gives the possibility to optimize cable length in order to avoid storing extra length under racks which is not possible in LHCb due to space limitations. Another advantage of this installation method is that probability of damaging cables when they are installed is less important (no risk to pull out wires in a connector).

After connector installation, all copper cables are electrically tested (continuity and short).

VIII. OPTICAL FIBER LINKS

A total of more than 7000 optical links is foreseen to be installed in the LHCb experiment. A relatively thick trunk fiber cable with 96 optical fibers organized in 8 groups of 12 fibers each is chosen for the long distance installation. On both ends, near the sub-detectors in racks and in the counting house, this cable ends in optical patch panels. The reason for this choice of cable has been made for the following reasons: reduce cross-section; a trunk cable thicker than individual optical fibers is more robust; all electronics readout boards have MPO-12 connectors with 12 fibers per connector.

Figure 9: Picture of one end of a multi-ribbon optical fiber trunk cable

The links connecting the detector with the counting house do generally not allow for retransmission of corrupted data and transmission errors will therefore result in erroneous event data. It is therefore mandatory to achieve the lowest bit error ratio (BER) possible both at installation and during operation.

Using the GOL serializer in fast 32bit mode, clocked by the LHC frequency, results in a physical serial data rate of 1.6 Gbit/s per optical link. This means a total bandwidth of 11.2 Tbit/s. Assuming a BER of 10^{-13} errors/bit results in ~1 error/s over the 7000 links. It is therefore clear that a BER, orders of magnitude better than 10^{-13} must be achieved. Therefore, particular care is taken during and after installation. Optical fiber handling [7] recommendations are given to users and extensive tests are performed. To keep testing time within acceptable limits and still assure link reliability as high as possible, a qualification scheme introducing extra attenuation has been chosen. The aim is to verify a BER of 10^{-12} with an additional attenuation of 6dB. These test conditions should assure that a much higher BER will be achieved in normal operation [8].

After installation of all multi-ribbon optical fiber cables, every single fiber link is tested (basic optical attenuation measurement). More extensive in situ tests and BER measurements are possible with final electronics modules as they contain this functionality.

IX. GROUNDING

In addition of its essential role in safety, the earth network connecting all metallic structure as well as the electrical equipments in an experiment as LHCb can serve as a base to install a heavily interconnected grounding network [9]. The purpose of such a grounding mesh in the experimental cavern is to reduce as much as possible the impedance between sub-detectors and counting house and more generally between equipments communicating to each other.

The safety earth cabling in LHCb connects all metallic structures and electrical equipments to the secondary star points of the mains transformers as well as an earth cable running along the cavern walls. This safety earth is also linked to the LHC machine earth underground and a connection is made at every LHC pit to the surface where earth electrodes are installed in the soil.

In order to complete this earth network to make a proper grounding network in LHCb, all metallic structure (rolling bridge beams, metallic supporting rails, other structures) are interconnected when possible on both sides of the cavern, detector side and counting house side [10]. In addition, a ground conductor of 120mm2 is installed every 4 cable ducts along the cavern walls. Cable ducts are connected to this ground every 5 meters.

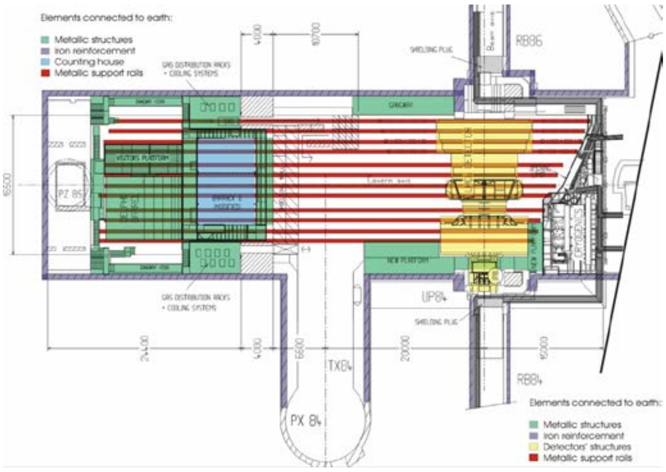

Figure 10: Overview of grounding in the experimental cavern

At all levels of the counting house, beams supporting racks in the false floor are interconnected to copper ground bars and cooling pipes. These copper ground bars interconnect all electronics racks. This ground structure in the counting house is connected to the general grounding in the cavern via ground conductors, metallic structures and cable ducts.

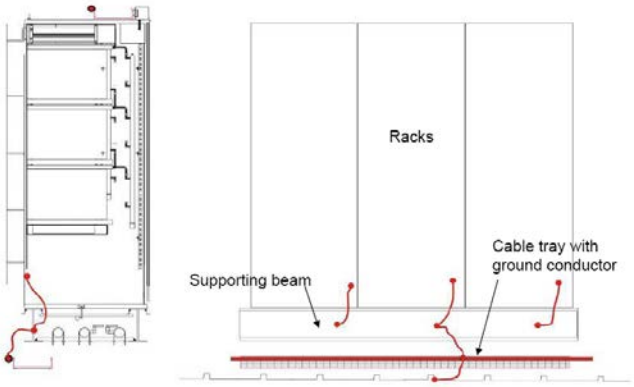

Figure 11: Side view of the rack grounding in the counting house false floor

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